Use of near infrared spectroscopy for characterization of wood

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Introduction

Near Infrared (NIR) spectroscopy can be used to rapidly and accurately measure the chemical and physical properties of a wide variety of biomass materials. NIR has several advantages over alternative spectroscopic tools since the samples require little, if any, preparation, the analysis can be done very rapidly, at very low-cost, and portable spectrometers are available. NIR can also be used for process control. Many of the NIR techniques that have been developed for use by the chemical, food processing and agriculture industries can be applied to the characterization of biomass. The examples described in this paper involve a five-step process. First, a set of samples with known properties, e.g., chemical composition or physical property, is required. Second, the NIR spectra of this set of "known" samples are collected. Third, the spectra and the property of interest are correlated using one of several multivariate techniques, e.g., project to latent structures (PLS) modeling. Fourth, the reliability of the correlations is validated using both statistical and chemical information. Finally, the validated model can be used to predict the properties of interest for unknown samples.

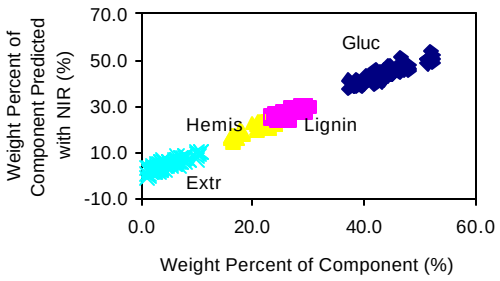

Figure 1. Correlation between the true and predicted chemical composition of eight softwood species.

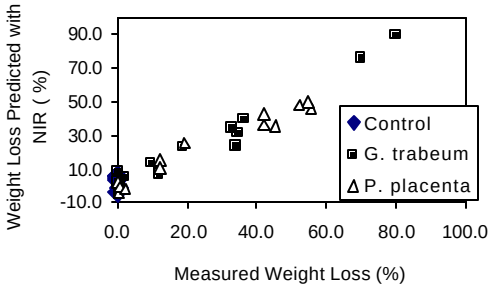

Figure 2. Correlation between the true and predicted weight loss for spruce exposed to different types of brown rot fungi.

Rapid Chemical Analysis

The chemical properties of a variety of biomass samples have been evaluated using the process outlined above. These samples include softwoods, hardwoods, agricultural residues, biomass process intermediates, and decayed wood. In all these examples NIR techniques accurately predicted the chemical composition of the biomass samples. Most of the correlation coefficients between the "true" and "predicted" chemical composition were above 0.8 and the prediction errors were similar to the measurement errors of the wet chemical methods used to establish the "true" chemical composition. Figure 1 shows the correlation between the true and predicted chemical composition of eight different softwood species. Figure 1 shows the generality of the NIR method since the chemical composition of eight softwood species are predicted from one model. Figure 2 shows that the weight loss of decayed wood can also be monitored with NIR. The correlation between weight loss and NIR spectra can also be used to detect subtle changes in the chemical composition of wood exposed to different species of brown-rot decay fungi.

Measuring Physical Properties

In addition to chemical properties, the physical properties of wood can also be measured with these NIR techniques. For example, the strength and stiffness both softwoods and hardwoods can be predicted from their NIR spectra. More importantly the strength and stiffness of dry wood can be predicted from the NIR spectra of wet wood.

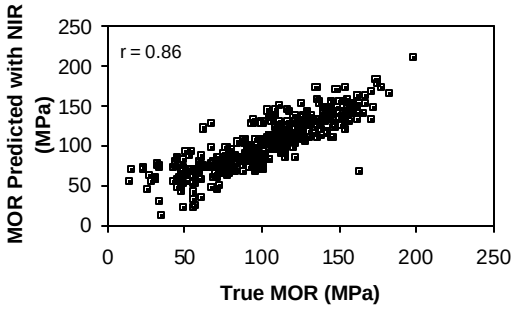

Figure 3. Correlation between the true and predicted strength of four different southern pine species.

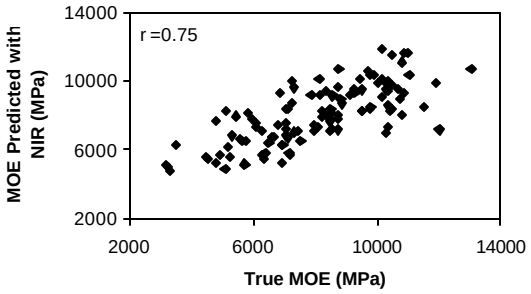

Figure 4. Correlation between the stiffness of dry poplar and the stiffness predicted from the spectra taken from wet poplar.

Figure 3 shows the correlation between the true and predicted stiffness for four southern pine species (loblolly, slash, shortleaf and longleaf). Figure 4 shows the correlation between the strength of dry poplar and the strength predicted from the spectra of wet poplar. Figures 3 and 4 demonstrate that, in addition to chemical information, the NIR spectra contain information about the mechanical properties of the wood substrate. The results in Figure 3 show that a single model can be used to predict the mechanical properties of four species of southern pine. The same correlations are obtained for the ultimate bending strength or modulus of rupture of southern pines. Similar predictions of mechanical properties can also be obtained with western softwoods and hardwoods. The results in Figure 4 show that the presence of water does not obscure the underlying molecular features that allow for prediction of mechanical properties. The ability to measure the strength properties of wet wood opens up the opportunity for using these NIR techniques for field sampling. The NIR spectra also contain information on the density, microfibril angle and the orientation of the wood fibers.

Conclusions

The results highlight the value and potential of using NIR techniques to measure the chemical and physical properties of wood. These NIR techniques have been used for years for both research and industrial applications, and should be rapidly adopted for the analysis of biomass.